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A NOVEL TRAJECTORY OPTIMIZATION METHOD FOR MARS ATMOSPHERIC ENTRY

Abstract

Trajectory optimization for Mars atmospheric entry is an important prerequisite for the implementation of autonomous guidance and navigation. A well designed entry trajectory can preplan the entry scenario meeting multiple constraints, which increases the safety and accuracy of a landing mission. Meanwhile, in order to release the burden of the guidance and control system in descent and landing phases for a pinpoint landing, a fixed parachute deployment condition may be preferred. In this paper, a novel trajectory optimization method for Mars entry phase is proposed, and the feasibility of using genetic method to solve the trajectory optimization problem is demonstrated. In order to improve the navigation capability, a Mars entry navigation scenario using radiometric measurements from multiple ground beacons is considered, and the determination of Fisher information matrix is used to quantify the degree of observability. The integration of determination of Fisher information matrix reflecting the overall navigation performance during the entry phase is chosen as the performance index which should be maximized. For reaching a precise parachute deployment condition, a backward integration is used to eliminate the strong terminal constraints. Meanwhile, a series of discrete collaboration points are selected based on the value of dynamic pressure which indicates the control capability. The continuous bank angle acceleration, which is regarded as control variable, can thus be approximated by the bank angle accelerations at these collaboration points using a cubic interpolation method. Given certain parachute deployment conditions, the trajectory of entry vehicle can be calculated based on Runge-Kutta backward integration. Therefore, the degree of observability of Mars entry navigation respect to the entry trajectory is derived based on the bank angle accelerations at collaboration points. The optimal control problem can thus be transformed to a nonlinear parameter optimization problem. With the consideration of path constraints of heat rate, dynamic pressure, and line-of-sight visibility of beacons, together with the terminal constraint of entry velocity, the trajectory optimization problem can be solved by a genetic algorithm. Above all, the control set corresponding to the parachute deployment condition is determined and analyzed based on the backward integration. Furthermore, trajectory optimization results of a Mars entry navigation scenario using three ground beacons demonstrate that the proposed trajectory optimization is more efficient than Gauss pseudospectral method using the same number of nodes and similar simulation time.